DEFENCE
SCIENCE & TECHNOLOGY

3 Apr 2003

Impact to Defence of Lessons Learnt using Modern Precision Strike Weapons

Nicola K. Molloy

DSTO-GD-0360

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Nicola K. Molloy

Weapons Systems Division
Systems Sciences Laboratory

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ABSTRACT

This report details research performed in the area of air-to-surface, precision strike weapons. The open literature has been reviewed and documents that relay information on precision weapons used in military operations over the last 20+ years have been studied. The points considered during this research include; intelligence support and operations planning; time critical targeting (mobile and relocatable); effects of weather and countermeasures; weapon use and effectiveness analysis; timely combat assessment; and the relevance to the ADF. These are discussed in relation to the lessons learnt from three of the military operations fought in the last half-century. Namely, Operations Desert Shield/Storm, Allied Force and Enduring Freedom.

Published by

DSTO Systems Sciences Laboratory
PO Box 1500
Edinburgh South Australia 5111 Australia

Telephone: (08) 8259 5555
Fax: (08) 8259 6567

AR-012-604
April 2003

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Executive Summary

Purpose

Precision Guided Munitions have been used extensively by other countries in the last 20+ years. This report investigates the lessons learnt by those countries that could become important to the Australian Defence Force in relation to the acquisition of modern precision strike weapon systems. The points considered for discussion include; intelligence support and operations planning; time critical targeting (mobile and relocatable); effects of weather and countermeasures; weapon use and effectiveness analysis; timely combat assessment; and the relevance to the ADF. These points are considered in relation to three wars fought in the last half-century. Namely, the conflicts in Iraq/Kuwait, Kosovo and Afghanistan.

Principal Findings

The principal findings that are important to the ADF are detailed below and encompass the lessons learnt from the conflicts listed.

Intelligence support and operations planning - Precision weaponry requires precision intelligence. The current tempo of operations requires significant information regarding the battle space, and smarter intelligence, surveillance and reconnaissance assets, coupled with an increase in their sensor and communications capabilities. The lessons for the ADF here pertain to the affordability of such weapons in an attempt to enable this higher tempo of operations.

Time critical targeting - To achieve this level of targeting capability a decrease in the sensor-to-shooter loop is needed. Currently, the loop is being closed to around 10 minutes by the US, which they believe is viable for today's mobile and relocatable targets. This affects the ADF on all levels; there are limitations in relation to the ADF's intelligence and targeting support capabilities; and there is a requirement for a high operational tempo, where network centric warfare is the possible key to success.

Effects of weather and countermeasures - Adverse weather is one of the main problems relating to the use of precision weaponry. The ADF must consider its financial position when using PGMs and therefore should have distinct preferences toward those weapons whose sensors are not affected by the adverse weather conditions predominant in many battle space environments. The enemy's use of countermeasures and camouflage are also an important consideration when deploying PGMs. The ADF cannot afford to deploy a munition on a false target.

Weapon use and effectiveness - The incorrect "one target, one bomb" claim for Laser Guided Bombs (LGB) is an important statement for the ADF as its current stockpile includes such weapons and therefore the cost of deploying such weapons should be taken into account.
Timely combat assessment - The work to improve the sensor-to-shooter timeline is extremely important to the ADF because of the need to provide accurate information about the battle space to all of the necessary platforms and command personnel. The accuracy and timeliness of information has the ability to decrease the costs that exist due to extra strikes being made on targets that have already been destroyed.

Results in Brief

Desert Storm

- All of the guided munitions used in Desert Storm required clear weather to enable their various infrared, electro-optical and laser sensors and designator systems to deliver munitions.
- Claims by manufacturers of LGBs can be summarised by the phrase "one target, one bomb." This claim was not validated in a single case. In fact, the average number of LGBs released per target was four; no fewer than two were dropped on a single target; six or more were dropped on 20 percent of targets; and eight or more dropped on 15 percent of the targets.
- More than 44 tons of unguided and 11 tons of guided ordnance was delivered against targets that were later assessed as being destroyed. Still more munitions were delivered against targets not successfully hit.
- The fundamental sensor limitations of coalition aircraft, coupled with the effectiveness of the Iraqi deployment tactics (including the use of decoys), suggest that there were only a few mobile SCUD launchers destroyed by Coalition aircraft or Special Forces.
- In this campaign, munitions cost was inversely proportional to use (i.e. higher cost ≡ lower usage).

Allied Force

- Further enhancement of intelligence, surveillance and reconnaissance sensors and the targeting process is needed to be able to employ precision munitions against fixed and mobile targets and to retarget those weapons dynamically.
- There still remains an effective role for non-guided munitions.
- Effective real-time targeting may require that aircraft have the capability to change weapon fuse settings while airborne.
- The need for rapid targeting and retargeting of aircraft and preferred munitions against known and emerging targets was again validated.
- In order to achieve precision engagement, precision intelligence is required.

Enduring Freedom

- Improvements to intelligence, surveillance and reconnaissance, and networking capabilities have proven to be vital to the success of this operation.
- The general need for an integrated seamless network of information will form the backbone of future network centric warfare.
- Only when a clear picture of the battlefield is assured and that knowledge is shared between the many platforms and fighting forces, can the maximum potential of precision guided munitions and other high-tech weaponry be attained.

Contents

Glossary

AAA	Anti-Aircraft Artillery
ADF	Australian Defence Force
AF	Air Force
ARM	Anti Radiation Missile
BDA	Battle Damage Assessment
BUFF	"Big Ugly Fat Fellow"
C^2	Command and Control
C^3	Command, control and communications
CALCM	Conventional Air Launched Cruise Missile
CEM	Combined Effects Munition
CIA	Central Intelligence Agency
DLIR	Downward Looking Infrared
DMA	Defence Mapping Agency
DMPI	Desired Mean Point of Impact
DoD	US Department of Defence
EO	Electro-optical
FLIR	Forward Looking Infrared
FRY	Former Republic of Yugoslavia
FSTC	Foreign Science and Technology Centre
GPS	Global Positioning System
HAB	Hardened Aircraft Bunker
HARM	High-speed Anti Radiation Missile
IADS	Integrated Air Defence System
INS	Inertial Navigation System
IR	Infrared
ISR	Intelligence, Surveillance and Reconnaissance
JDAM	Joint Direct Attack Munition
JSOW	Joint Stand Off Weapon
KTO	Kuwaiti Theatre of Operations
LANTIRN	Low Altitude Navigation and Targeting Infrared at Night
LGB	Laser Guided Bomb
MEL	Mobile Erector Launcher used for mobile missiles
MoD	UK, Ministry of Defence
MUP	Yugoslav interior forces
NAC	North Atlantic Council
NATO	North Atlantic Treaty Organisation
NBC	Nuclear, Biological and Chemical

OSCE	Organisation for Security and Cooperation in Europe
PGM	Precision Guided Munition
PGW	Precision Guided Weapon
RG	Republican Guard
RGFC	Republican Guard Forces Command
SAD	Serbian Air Defences
SAM	Surface to Air Missile
SLAM	Standoff Land Attack Missile
SOF	Special Operations Forces
TEL	Transportable Erector Launcher
TLAM	Tomahawk Land Attack Missile
UAV	Unmanned Aerial Vehicle
UK	United Kingdom
UN	United Nations
US	United States
USAF	US Air Force
VJ	Yugoslav Army
WCMD	Wind Corrected Munitions Dispenser

1. Introduction

As American strategist, Eliot Cohen, has noted, 'air power is an unusually seductive form of military strength because, like modern courtship, it appears to offer gratification without commitment' [1]. Consider this point as a technical argument toward the acquisition and use of Precision Guided Munitions.

Precision is a relative word when used in relation to munitions. It is relative to the period about which one is concerned. Although seeking precision through accurate aim remains a fundamental priority of military power, the historical record indicates that the best combination is the trained operator on a smart platform with smart sensors dispensing smart weaponry [2].

This report intends to analyse the impact to Defence of lessons learnt from recent conflicts where modern Precision Strike Weapons have been used against defined military missions and objectives in relation to the following objectives:

a. Intelligence support and operations planning;
b. Time critical targeting (mobile and relocatable);
c. Effects of weather and countermeasures;
d. Weapon use and effectiveness analysis;
e. Timely combat assessment; and
f. Relevance to the ADF.

A discussion follows on the above points in relation to three main wars fought during the last half-century. Namely, the conflicts fought in Iraq and Kuwait, Kosovo and Afghanistan.

Appendix A highlights the timeline details involved and Appendix B shows the technologies used during these conflicts.

1.1 Background Information

1.1.1 Sensor Systems

The issue of sensors and sensor systems requires more attention than is attainable through the subject of this paper. However, it is important to understand some of the basic principles involved in the use of sensors because the effectiveness of any PGM is highly reliant upon the type of sensor used, which portion of the electromagnetic spectrum that sensor monitors, its resolution and speed.

The electromagnetic (EM) spectrum (Figure 1, [3]) is a chart showing frequency or wavelength of electromagnetic radiation (EMR). The fundamental unit of electromagnetic radiation is known as the photon [4]. Variations in photon energies (expressed in Joules or ergs) are tied to the parameter *wavelength* or its inverse*frequency*. Photon's move at the speed of light and also as waves; these waves follow a pattern described in terms of a sine (trigonometric) function. The distance between two peaks on a wave is its wavelength. The total number of peaks that pass by a reference in a second is that wave's frequency [4].

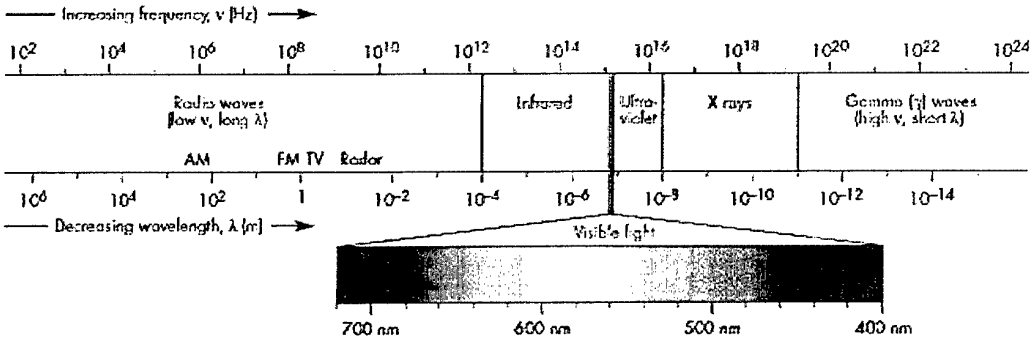

Figure 1: The Electromagnetic Spectrum [3]

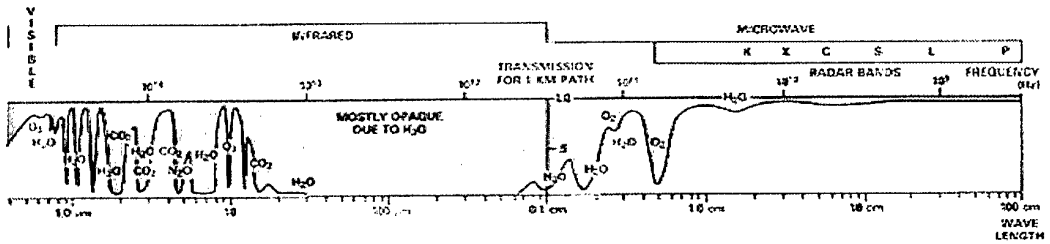

Figure 2: Atmospheric Absorption [4]

A narrow range of EMR extending from 400 to 700 nm (0.4 to 0.7μm), the interval detected by the human eye, is known as the *visible region*. Over the years, scientists have divided the EM spectrum into regions or intervals and applied descriptive names to them. The regions of most interest to this study are those from the visible, infrared, microwave, and radar where the infrared region spreads from 700nm to 0.001m (in wavelength), the microwave region spreads from 0.001 to 1m (including all of the interval used by radar systems) and the radio wavelength range is >1m.

Most sensing is conducted above the Earth either within or beyond the atmosphere. The gases in the atmosphere interact with solar irradiation and with radiation from the Earth's surface. The atmosphere itself is excited by EMR so as to become another source of released photons. Figure 2 [4] shows relative atmospheric radiation transmission of different wavelengths. The blue zones mark minimal passage of incoming and/or outgoing radiation, whereas the cream areas denote atmospheric windows, where the radiation has little interaction with the air molecules and is therefore not absorbed.

Many sensing instruments operate in one of these atmospheric windows by making their detectors tuned to specific frequencies (hence optical, infrared and radar sensors) that pass through the atmosphere. For the purposes of this study, it is important to note that the atmosphere is nearly opaque due to EMR in part of the mid-IR and all of the far-IR regions. In the microwave region, by contrast, most of this radiation moves through unconstrained, so radar waves (shown in Figure 2, denoted as K through P bands) can

reach the surface (although raindrops can cause backscattering, allowing it to be detected [4]).

1.1.2 The Gulf War

The conflict in the Persian Gulf began on August 2, 1990 after grievances between Iraq and Kuwait over oil pricing could not be resolved. The initiation of Operation Desert Shield occurred on August 7, subsequent to Iraq's invasion of Kuwait. Its goals were to liberate Kuwait and force the intruders back to Iraq. The efforts of the UN to find a peaceful solution proved futile and by Jan 15, 1991 the deadline for peace had passed; Operation Desert Storm began the next day. This battle, fought primarily as a 43 day ([5], [6] & [7]) sustained air campaign against Iraq, lasted until February 28, 1991. It was the first large-scale air war fought since Vietnam and was thought of by some as possibly the most successful war of last century. The use of high technology combined with older machinery was critical to the success of the conflict. By historical standards, the intensity of the air campaign was substantial, with the US deploying approximately 1,600 combat aircraft. After the air campaign, the allied forces Desert Sabre ground offensive began and lasted only 100 hours, crushing the war-weary Iraqi army.

1.1.3 The War Fought for Kosovo

Operation Allied Force began with military objectives to "Degrade and damage the military and security structure that President Milosevic (Former President of Yugoslavia) used to depopulate and destroy the Albanian majority in Kosovo"[8]. The air strikes began on March 24, 1999 against Serbian military targets in the Former Republic of Yugoslavia. These strikes continued on the premise of full Serbian compliance with NATO demands. The Yugoslavs displayed tenacity by thinking that they could destroy the Kosovar Liberation Army in a matter of days and assumed that NATO would never launch air strikes against them. They also assumed that NATO would not remain unified long enough to carry out significant air attacks. As the battle progressed, these assumptions proved to be deadly wrong. Operation Allied Force was originally divided into five phases [9]:

0. Released on January 20 1999, air forces of NATO shifted for the accommodation of practice flight operation to their operational airfields.
1. Commenced on 24 March 1999 with attacks on the Serbian Integrated Air Defence Systems and the creation of air superiority over Kosovo.
2. Authorised on March 27 1999 to extend attacks to the security forces infrastructure military in Kosovo and reinforcement forces.
3. Would expand air operations but was not authorised because a month into the air campaign NATO realised that a constrained, phased approach was not effective. Instead, the air campaign widened to produce the strategic effects in Serbia proper.
4. To redeploy forces as required.

One of the fundamental factors in the conclusion of Allied Force was NATO's intransigent nature. It failed to deflect from its goals. Both the precision and persistence of the air campaign were essential in convincing Milosevic that it was time to end the fight.

Bombing was suspended on June 10, 1999, and on June 20, the campaign halted when the UN Security Council voted 14 to 0 (with China abstaining) to adopt the peace resolution in Kosovo.

1.1.4 The War Against Terrorism

The tragedy of the September 11, 2001 attacks on the United States gave rise to the current military action against terrorism throughout the world. The US led military campaign in Afghanistan came with swift success despite the problems of a low-tech asymmetric enemy force.

Initial attacks began on 7 October, 2001 against Taliban and al-Qaeda targets in Afghanistan with early goals to suppress the air-defence systems available to the Taliban and to create conditions for sustained anti-terrorism and humanitarian relief operations in the country. The difference between this and previous conflicts was that the allied forces were targeting essentially irregular forces. The targets were generally not high value - al-Qaeda and the Taliban having no armies, navy or air forces. This allowed for the gathering of better intelligence and targeting information to enable greater precision in general.

2. Operation Desert Storm

"Gulf lesson one is the value of airpower...(it) was right on target from day one. The Gulf war taught us that we must retain combat superiority in the skies...Our air strikes were the most effective, yet humane, in the history of warfare."

- Former President George Bush
29 May 1991[10]

2.1 Air Campaign Objectives

During the entire conflict, there was a distinct lack of both planning and strategic guidance. Most target categories used to structure the air campaign did not constitute homogenous sets, although the initial designation of the campaign was a four-phase attack system [5].

Phase 1 - The strategic air campaign - would start the attack and address the three centres of gravity:

(1) The National command authority;
(2) Nuclear, Biological and Chemical capability; and
(3) The Republican Guard forces and most of the 12 target sets listed below.

Phase 2 - The attainment of air superiority in the Kuwait theatre of operations - was initiated simultaneously with phase I.

Phase 3 - Battlefield preparation - involved attacking Iraq ground forces including the Republican Guard.

Phase 4 - The ground offensive - where Coalition ground forces would be supported by Coalition air forces.

The planning for phase I was based on attaining the five military objectives listed below. Under each objective is a list of the target sets that would be attacked to secure it [10].

1. Isolate and incapacitate the Iraqi regime:
   - Leadership command facilities
   - Crucial aspects of electricity production facilities that power military and military-related industrial systems
   - Telecommunications and C^3 systems
2. Gain and maintain air supremacy to permit unhindered air operations:
   - Strategic Integrated Air Defence Systems, including radar sites, SAMs and IADS control centres
   - Air forces and airfields
3. Destroy NBC warfare capability:
   - Known NBC research, production and storage facilities
4. Eliminate Iraq's offensive military capability by destroying major parts of key military production, infrastructure and power projection capabilities:
   - Military production and storage sites
   - Scud missiles and launchers, production and storage facilities

- Oil refining and distribution facilities, as opposed to long-term production capabilities
- Naval forces and port facilities

5. Render the Iraqi army and its mechanised equipment in Kuwait ineffective, causing its collapse:
   - Railroads and bridges connecting military forces to means of support
   - Army units to include Republican Guard Forces Command in the Kuwaiti Theatre of Operations

Thus, the 12 target categories listed for Operation Desert Storm are [5]:

1. Leadership command facilities
2. Electricity production facilities
3. Telecommunications and C^3 nodes
4. Strategic IADS
5. Air forces and airfields
6. NBC weapons research, production and storage facilities
7. Scud missiles, launchers and production and storage facilities
8. Naval forces and port facilities
9. Oil refining and distributing facilities
10. Railroads and bridges
11. Iraqi army units including the RG in the KTO
12. Military storage and production sites

The Air Staff planning group characterised strategic target sets as follows [10]:

- Leadership – Saddam Hussein's command facilities and telecommunications
- Key production – electricity, oil refining, refined oil products, Nuclear Biological and Chemical, other military production and military storage
- Infrastructure – railroads, ports and bridges (initial plans expected to attack only railroads; later, ports and bridges were added when the theatre plan expanded to include attacks on the fielded forces in the KTO)
- Fielded forces – air defences, naval forces, long-range combat aircraft, missiles, and airfields

Targets in each category were identified, imagery obtained, weapons and aim-points chosen and an attack flow plan assembled using aircraft scheduled to deploy.

The successes and failures of the strategy and planning of Operations in the Persian Gulf are documented in Table 1 [5]. This table outlines the desired/planned effects for each target set and then gives the actual achieved results in relation to each set.

2.2 Munitions Use in the Air Campaign

This section is a discussion on the conditions within the Gulf, the planned versus actual use of air-to-ground munitions used in the campaign, and aircraft survivability.

2.2.1 Operating Conditions

The flat, open terrain of the Kuwait Theatre of Operations, without significant foliage or sharp ground contours, exposed targets to sensors and made all but the

Table 1: Operational-Strategic Summary [5]

Target Sets*	Desired/Planned Effects	Actual Results
IADS (SAD) & Airfields (A)	Early air superiority • Suppression medium-high air defences throughout Iraq • Contain/destroy Iraqi AF	IADS blinded/ intimidated/ suppressed • Low-altitude AAA, IR SAMs remained Iraqi AF bottled up on bases • 2 air-to-surface Iraqi shooter sorties? 375 of 594 HABs destroyed/damaged • Iraqi AF flees to Iran (starting 25 Jan 91)
Naval (N)	Attain sea control • Permit naval operations in northern Persian Gulf	All Iraqi naval combatants sunk/neutralized • Other vessels sunk Silkworms remained active throughout war
Leadership (L) & Telecomms/C3 (CCC)	Pressure/disrupt governmental functioning Isolate Saddam from Iraqi people, forces in KTO	Unknown degree of disruption • Neither decapitation nor Saddam's overthrow Telecomms substantially reduced • Links to KTO never completely cut • International communications cut
Electricity (E) & Oil (O)	Shut down national grid • Minimize long-term damage Cut flow of fuels/ lubricants to Iraqi forces • No lasting damage to oil production	Rapid shutdown of grid • Down 55 percent by 17 Jan, 88 percent by 9 Feb • Lights out in Baghdad Some unintended damage to generators Refining capability down 93 percent (Day 34) Destroyed about 20 percent of the fuel/ lubricants at refineries & major depots • 43 day war precluded long-term effects
NBC (C) & SCUDs (SC)	Destroy chem/bio weapons • Prevent use against Coalition • Destroy production capability Destroy nuclear program • Long term Prevent/suppress use • Destroy production & infrastructure • Keep Israel out of the war	Some chemical weapons destroyed • But most survived (UN Special Comm) • Chemical use deterred • No biological weapons found (UN) Nuclear program "inconvenienced" (UN) • Most program elements survived Firings somewhat suppressed, not salvos • SCUD operations pressured • Aircraft destroyed few, if any, MELs/TELs
Railroads/ Bridges (RR)	Cut supply lines to KTO • Prevent retreat of Iraqi forces	All important bridges destroyed • Many Iraqi workarounds Short duration of war limited effects
Republican Guard (RG) & Other Ground Forces in the KTO	Destroy the RG Reduce combat effectiveness by 50 percent (armour, artillery) by G-Day	RG immobilized • Attrition by G-Day <50 percent • Some RG units and 800+ tanks escape Front-line forces waiting to surrender or destroyed in place • Attrition by G-Day >50 percent • Morale destroyed by air
*The target categories shown subsume the Military support (MS), Breaching targets (BR), and KTO SAMs.		

smallest objects hard to conceal completely. The desert climate provided a strong heat contrast for targets on the desert floor, especially at night and the flat monochrome nature of much of the terrain presented a good optical contrast during much of the day for EO systems, by making objects shadows - when camouflaged - salient.

Inversely, adverse weather such as clouds, rain, fog and even haze and humidity was the worst in the region for at least 14 years. Records detail that there was at least 25 percent cloud cover on 31 of the war's 43 days, more than 50 percent cloud cover on 21 days and more than 75 percent on 9 days [6]. In addition, there were occasionally violent winds and heavy rains.

Table 2: Desert Shield/Desert Storm U.S. Weapons Expenditures and Percent of Total U.S. Expenditure [5]

Munition types:	Guided bombs, all types	Anti-radiation missiles (principally HARMs)	Air-to-surface missiles (Maverick for AF; principally Walleye for N and MC)
Air Force	8,456 (90 percent)	1,120 (55 percent)	5,255 (96 percent)
Navy	623 (7 percent)	679 (33 percent)	147 (3 percent)
Marine Corps	263 (3 percent)	240 (12 percent)	46 (1 percent)
Totals	9,342	2,039	5,448
Royal Air Force (UK)	1,126	112 Air- Launched Anti-radiation Missiles (ALARMs)	N/A
French Air Force	N/A	N/A	Approx 60 AS-30s (laser-guided missiles)
Grand Totals	10,468 (U.S. 89 percent)	2,151 (U.S. 95 percent)	5,508 (U.S. 99 percent)

2.2.2 Air-to-Ground Weapons Systems Use

The primary munitions used in Desert Storm were the GBU-12/24/27 Laser Guided Bombs (LGB), the GBU-15 TV/IR guided bomb and the AGM-65 Maverick missile.

The development of LGBs dramatically improved the accuracy of weapon guidance and delivery. Laser guided munitions offered advantages in standoff and accuracy over other types of free-fall weapons dropped by the USAF. During Desert Storm, the F-111F and the F- 117 accounted for the majority of the guided bomb tonnage delivered against strategic targets [6]. Between them, they delivered at least 7.3 million pounds of guided bombs against strategic targets (more tonnage was delivered by the F-111F against Offensive Counter Air static targets).

The GBU-15 is an unpowered glide weapon used to destroy high value enemy targets. Its effective standoff range is greater than that of laser-guided munitions, since there is no need to have acquired the target before its release. During Desert Storm, all of the 71 GBU-15 modular glide bombs used were dropped from F-111F aircraft [6]. Most notably, GBU-15's were the munitions used for the destruction of oil manifolds on the storage tanks to stop oil from spilling into the Gulf.

The AGM-65 Maverick is a tactical, air-to-surface guided missile designed for close air support, interdiction and defence suppression missions. Maverick success rate (successful launch and guidance to the target) was 80 to 90 percent for the more than 5,100 AGM-65s fired [10]. The missiles deployed by F-16s and A-10s to attack armoured targets in the Persian Gulf played a large part in the destruction of Iraq's significant military force.

Of the total munitions used against strategic targets, approximately 95 percent were unguided. Guided missiles constituted only about 5 percent of the total munitions usage but these accounted for 84 percent of the total weapons cost of the air campaign [6]. These percentages characterised not only the overall effort but also the proportion of guided and unguided tonnage delivered in the campaign. Table 2 [5], shows that 89 percent of guided bombs and 99 percent of air-to-surface munitions deployed during Desert Storm and Desert Shield were contributed by the US military.

The reasons given for the lesser use of precision munitions are [5]:

- Poor weather and conflict-induced environmental conditions, such as smoke from bombing, which degraded or blocked the targeting sensors required for the delivery of guided ordnance
- The comparatively high cost of guided bombs and resulting smaller inventories (pilots were frequently told to conserve guided bomb deliveries)
- Many strategic targets were large and therefore generally appropriate for the use of unguided ordnance

2.2.2.1 Sensor Performance

INFRARED

Certain target sensors and bombing systems gave an effective capability of operating at night. This is particularly relevant to IR systems such as the IR Maverick, Pave Tack and FLIR/DLIR. F-15E pilots also stated that they were 'exponentially more effective' with Low Altitude Navigation and Targeting Infrared at Night, than without. IR sensors proved to be important for night attack although pilots have given a variety of sensor limitations.

Effects of high altitude releases on IR sensor resolution – During the campaign, the majority of bombs were released from aircraft flying above 12,000 feet due to the restriction enforced after aircraft losses early in the air campaign during low altitude munition deliveries. Flying at higher altitudes provides relative safety from most air-defences but its result was a major compromise in terms of bomb accuracy and effectiveness.

Other hindrances to IR Sensors – Pilots also reported that a variety of environmental conditions, some natural, some conflict induced, impeded the capabilities of their IR systems.

ELECTRO-OPTICAL

EO sensor systems depend on both light and optical contrast for target searching and identification. This obviously depleted their use at night or in any significantly adverse weather conditions where the line of sight to the target was obscured.

The requirement for visual contrast between the target and its immediate surroundings imposed additional problems. For AGM-62 Walleye delivery, pilots reported that a target was often indistinguishable from its own shadow, which made it difficult to reliably designate the actual target. Additionally, low-light conditions at dawn or dusk often provided insufficient light for the required degree of optical contrast (this was overcome by using the "haze-penetrator" version of Walleye).

EO systems proved at least as vulnerable to degradation as other sensors and lacked full-time night capability.

RADAR

Most radar systems come with a distinct target discrimination problem. Despite this, they had the advantage of not being impeded by adverse weather conditions. This meant that only comparatively inaccurate unguided bombs could be delivered in poor

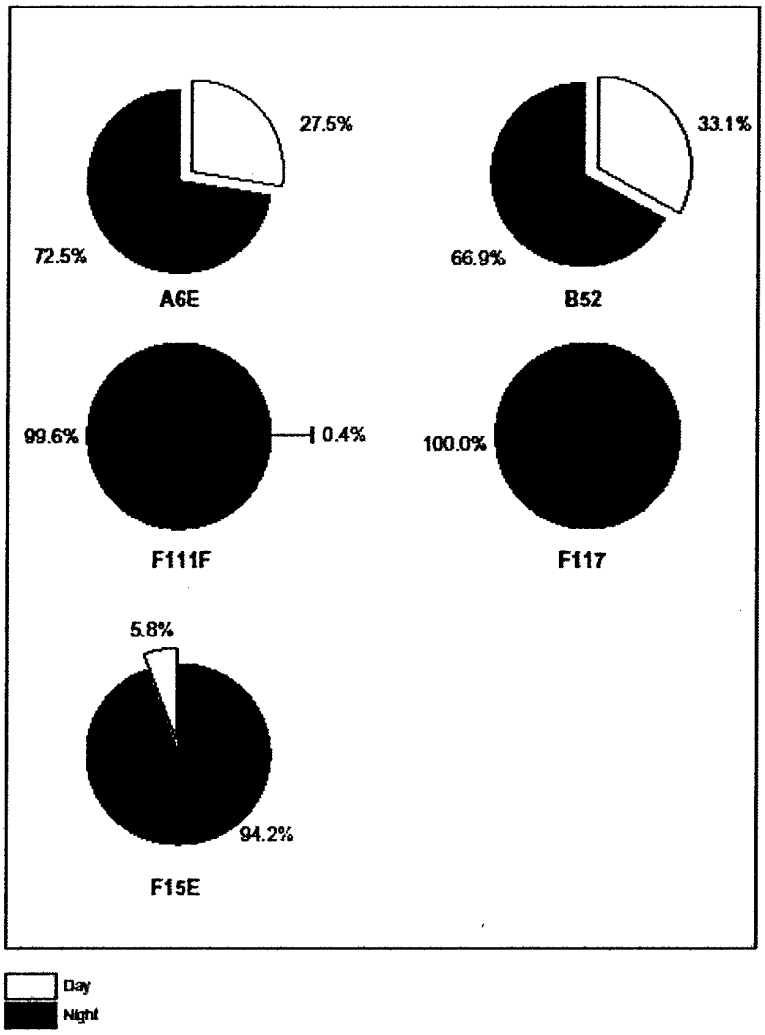

Figure 3: Percent of Day and Night Strikes for Selected Aircraft [5]

weather because basically all of the guided munitions used in Desert Storm required clear weather to enable their various IR, EO and laser sensors and designator systems to deliver munitions.

2.2.3 Aircraft Survivability

Most strikes against strategic targets, including nearly all by LGB-capable aircraft, were conducted at night. This apparent preference for nighttime operations (see Figure 3 [5]) seems most likely related to maximising aircraft survivability due to the fact that in Desert Storm, optically guided Iraqi IR Surface to Air Missiles and Anti-Aircraft Artillery were responsible for the largest number of aircraft casualties (losses and damage). In addition, operations at night provide optimal heat contrast for some targets as the sand cools faster than most objects in it. This factor improved the effectiveness of night attacks for aircraft with infrared targeting systems.

Compared to planners' expectations and by historical standards, the amount of aircraft lost or damaged was relatively low. The combination of the ban on low-altitude tactics after day two, the degradation of radar SAMs and the IADs in the early days of the war, and the fact that a high proportion of strikes were flown at night—which constituted another form of aircraft sanctuary—almost certainly was responsible for the lower than expected Coalition aircraft attrition rate.

2.3 Munitions Effectiveness in Desert Storm

This section is a discussion of the overall quality and scope of the weapon system performance data; the effectiveness of individual weapons systems; and the effectiveness of the air campaign achieving its specific objectives.

2.3.1 Battle Damage Assessment

Desert Storm was not planned, executed, or documented to satisfy the information needs of operations analysts or program evaluators. As a result, there are sometimes significant gaps in the data on weapon system performance and effectiveness, the latter as a result of insufficient BDA [6].

Few assertions about the gulf war could command as much agreement as the inadequacy of Battle Damage Assessment. The BDA process at the theatre level suffered from a lack of adequate systems, procedures and manpower and had difficulty trying to keep pace with the size, speed and scope of the air campaign. At the tactical level, few assets were available to collect BDA after artillery or air strikes. Communications down to this level were often not adequate to pass on reconnaissance results.

Technical limitations, such as the weather, inhibited the operators ability to identify and acquire targets and produce timely BDAs, which resulted in many unnecessary and expensive strikes on already destroyed targets. Reports from US AF, Navy and Marine flight crewmembers and those of other Coalition air forces agreed that they received little or no BDA on the targets they attacked during the entire war.

More than 44 tons of unguided and 11 tons of guided weapons were delivered on targets that were later assessed as being destroyed. Still more ordnance was delivered against targets not successfully hit. Many Iraqi hardened targets were hit by more than one LGB resulting from insufficient BDA prior to strike. Insufficient BDA sometimes prevented pilots from knowing at what point a target was destroyed. This in turn resulted in an increase in risks to Coalition pilots and aircraft by conducting additional strikes and an inability to fulfil Coalition objectives.

2.3.2 LGB Accuracy

Of the 167 LGBs dropped during the first five nights of Operation Desert Storm, 76 (45.5 percent) missed their targets due to pilot error, poor weather or technical malfunctions. During the first three weeks of the campaign, half of the strikes in Iraq needed diverting to new targets or postponing due to weather related problems.

Table 3: Manufacturers' Statements Compared to GAO Findings [6]

Manufacturer	Product	Statement	Findings
Texas Instruments	Paveway guidance for LGBs	"Deployable" in "poor weather/visibility" conditions.[1]	Clouds, smoke, dust and haze impose serious limitations on laser guidance by disrupting the laser beam.
		"TI Paveway III: one target, one bomb."[2]	Our analysis of a selected sample of targets found that no single aim point was struck by one LGB - the average was four, the maximum was 10.
		"LGBs accounted for only 5 percent of the total ordnance. But Paveway accounted for nearly 50 percent" of targets destroyed. [2]	Data were not compiled that would permit a determination of what percentage of targets were destroyed by any one munition type.

Pilots reported that the effectiveness of guided munitions decreased from higher altitudes because:

i. Targets were more difficult to designate with lasers
ii. Some computer software did not allow high-altitude bombing
iii. The LGBs were also subject to the effects of wind.

Manufacturers claims of "one target, one bomb" accuracy (see Table 3 [6]) proved false in the combat conditions of Operation Desert Storm. Figure 4 [6], shows the number of Paveway III LGBs that were delivered against 20 Desired Mean Points of Impact. This figure shows that the claims were not validated in a single case in Desert Storm. In fact, the average number of LGBs dropped per target was four; no fewer than two were delivered on each target; six or more were dropped on 20 percent of the targets; and eight or more were dropped on 15 percent of the targets [6].

These statistics are most probably due to the fact that more than one bomb was needed to inflict the required amount of damage on a target. It was also noted that insufficient BDA sometimes prevented pilots from knowing at what stage a target was sufficiently damaged, thus putting pilots and airplanes at risk in conducting extra strikes. Planners were also ordering the delivery of multiple bombs on a target because their BDA had shown that one bomb did not achieve target objectives or they did not believe the presumption that "one target, one bomb" was being achieved.

2.3.3 Planning and Intelligence

In Desert Storm, operational planners relied on their own intelligence sources to make the basic target selections - especially insofar as the strategic portion of the air campaign was concerned. Inevitably, this ad hoc arrangement tended to blur and confuse the relations between theatre intelligence and operations. The coordinates passed from planners were nowhere near as accurate as those the Defence Mapping Agency could provide through intelligence channels. This inturn produced frustration for the theatre and tactical commanders over the lack of coordination and timeliness in the dissemination of intelligence data.

[1] Texas Instruments "Paveway Laser-Guided Weapons" brochure, 1992.
[2] From a company advertisement in Aviation Week and Space Technology. (1991).

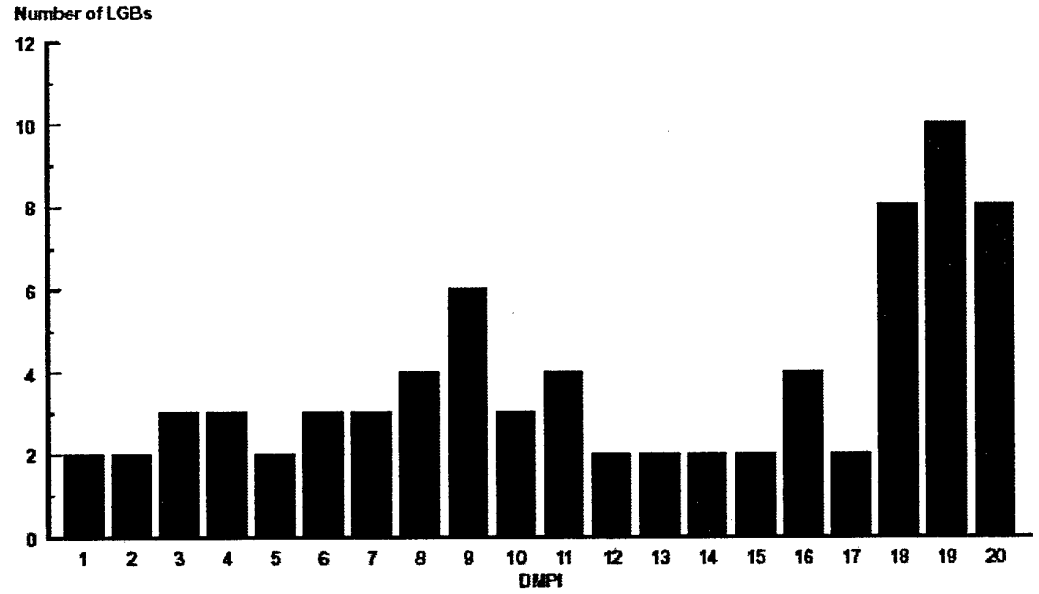

Figure 4: Paveway III LGBs delivered against specific point targets [6]

2.3.4 Effectiveness Against Mobile Targets

Over the 43 days preceding the ground campaign, approximately 37,500 strikes were conducted against Iraqi forces in kill box areas, targeting tanks, armored personnel carriers, and other tactical vehicles [6]. Because of the lack of data on munitions expenditure and because it was impossible to collect and compare BDA data to assess munition hit rates, it is also impossible to know exactly what level of effectiveness was achieved in Desert Storm.

During Operation Desert Storm, the 'Scud hunt' was largely useless. Even with the direction of a large amount of Coalition resources, the destruction of mobile launchers proved itself a relatively unattainable task. Within 10 minutes after a launch, a mobile Scud launcher could be anywhere within 10 kilometres of the launch site. Destruction of these launchers depended on time - the faster strike aircraft could get to the target the better the chance of destroying the launcher. Many sorties were diverted or replanned from their intended targets to hunt for and suppress the scuds.

The fundamental sensor limitations of Coalition aircraft, coupled with the effectiveness of the Iraqi deployment tactics (including the use of decoys), suggest that there were only a few mobile scud launchers destroyed by Coalition aircraft or Special Forces during the war.

The findings of both the Foreign Science and Technology Centre and the CIA show that attrition of armoured vehicles from guided munitions was most probably less than originally claimed. Even so, the air campaign still destroyed (or rendered unusable) less than half the Iraqi armour in the KTO.

By early February, the counter-scud effort seemed to be having an effect, although no destruction of mobile launchers was confirmed (probably due to lack of sufficient BDA).

Table 4: Findings on Desert Storm key objectives [6]

Target Set	Finding
Leadership & C^3	- 52 percent of leadership and 57 percent of C^3 targets were successfully destroyed or damaged. - Despite hits on C^3 nodes, Saddam was able to communicate with and direct Iraqi forces.
Oil & Electricity	- 80 percent of oil-refining capacity "damaged." - National electric power grid "eventually collapsed." - Early disruption of primary sources negatively affected entire war industry capabilities.
Scuds	- No known destruction of mobile Scud launcher. - Scud launches seemingly temporarily suppressed but end-of-war launches suggest large reserve may still exist. - Scud hunt level of effort overstated.
NBC	- 76 percent of known NBC targets fully successfully destroyed. - While known nuclear sites were moderately or severely damaged, overall program was virtually intact because only less than 15 percent of the facilities were known and therefore attacked.
Railroads & Bridges	- 67 percent of lines-of-communication targets fully successfully destroyed. - Iraqi ground forces experienced some shortages but overall, remained adequately supplied up to ground war start.
RG & other ground forces in the KTO	- Frontline troops and equipment apparently hit hard, but morale was apparently very low before the air campaign. - Static tactics of Iraqi ground forces aided targeting. - Some RG heavy armour divisions escaped with large inventory.

2.3.5 Effectiveness in Achieving Key Objectives

The following table (see Table 4 [6]) dictates the level of effectiveness in achieving the key objectives of the air campaign. These objectives cover nearly all of the 12 strategic target categories listed in § 2.1.

2.3.6 Iraqi Countermeasures

Iraqi countermeasures to degrade or impede the effectiveness of Coalition air attacks or communications were inconsistent and did not appear to have represented as much as could have been achieved.

Toward the end of the war, the Iraqi's ignited hundreds of Kuwaiti oil wells, creating vast plumes of black oil-based smoke, which seriously impeded visual observation and reconnaissance as well as the IR and EO weapon sensors and the laser designators on aircraft.

The Iraqi games against the Coalition F-117 and F-111F aircraft, which carried the only hard-target penetrators, included:

- Dispersing aircraft into the open airfields, where they could preclude Coalition aircraft from getting both a shelter and a combat aircraft with a single LGB
- Moving aircraft into the open regularly – every day or so – to make it difficult for Coalition planners to target individual aircraft;
- Dispersing aircraft off the airfields, increasing the area to be searched; and
- Exploiting the Coalitions reluctance to risk damage to cultural monuments such as Islamic Mosques by parking combat aircraft near them

The Coalition countered their vulnerability to the Iraqi air defences by flying into the heavily defended areas of Iraq escorted by F-4Gs, EA-6Bs or A-7s, firing radar homing

missiles to destroy the defences and by F-111s or EA-6Bs to jam Iraqi radars. The use of High-speed Anti-Radiation Missiles by Coalition air forces effectively neutralised both elements of Iraqi ground-based defences - AAA and SAMs - by suppressing the SAMs and thereby allowing the Coalition aircraft to fly above the lethal range of the AAA.

Electronic Warfare aircraft also played a central role in the neutralisation of the Iraqi air defence system. These aircraft proved themselves vital to mission success; only one of the one hundred mission packages flown from Incirclik during the war was dispatched without such an aircraft.

2.3.7 Cost and Performance of Munitions

As indicated earlier, the vast majority of munitions used in Desert Storm were unguided - approximately 95 percent - the inverse is true for cost. Approximately 84 percent of the cost of ordnance was attributed to the ~5 percent of munitions that were guided. Excluding the cruise missiles, the percentage of cost for guided ordnance only decreases to 75.9 percent. These figures represent only the cost of munitions expended during the conflict; they do not take into account the accumulation of cost per target (i.e. total cost of weapons expended per target, platform cost, cost of other weapons used to roll-back enemy defences). Although this is the case, the percentages above do show that greater individual weapon cost equals less weapons used.

2.4 Summary

Table 5 [6], summarises the important points on guided weapon strengths and weaknesses. The following is a précis on the lessons learnt from the conflict in the Persian Gulf, Operation Desert Storm.

2.4.1 Munitions Use

The two most notable discrepancies between original aircraft or munitions design and actual use in the conflict are:

1. The survivability decision to bar munitions deliveries from below 12,000 feet and
2. Most unguided munitions tactics, before the war, planned for low-altitude deliveries. The switch to medium-to-high deliveries meant that the accuracy of unguided munitions was greatly reduced.

2.4.2 Munitions Effectiveness

Aircraft targeting capabilities and PGMs were put to the test by periods of adverse weather as well as adverse conditions such as smoke from oil fires or dust from bombing. Even some of the milder weather conditions, including humidity, rendered precision bombing sensors either degraded or inadequate.

The results of analysis of munitions effectiveness did not support the claim for LGBs summarised by "one target, one bomb." Moreover, planners apparently ordered re-strikes either because BDA revealed that one bomb did not achieve target objectives or they did not believe that "one target, one bomb" was being achieved.

Table 5: Relative Strengths and Limitations of Guided Munitions [6]

Measure	Relative Strengths	Relative Limitations
Cost	No demonstrated strengths. LGBs, Mavericks and other guided munitions are much more expensive than unguided munitions.	High unit cost; cost ratio of LGBs to unguided unitary bombs ranged up to 48:1; for Mavericks, 164:1.
Survivability	Varying amounts of standoff capability avoided defences collated with the target. LGBs and other guided munitions used permitted medium and high-altitude releases while retaining accuracy, thus reducing vulnerability to AAA and IR SAMs.	Standoff capability did not negate defences not at the target.
Operating characteristics	Night-capable, clear weather (except for most EO systems); some correctable accuracy degradation from high winds.	Adverse weather conditions such as cloud, smoke, haze and humidity either eliminated or seriously restricted deployment. Sometimes required precise intelligence and more demanding mission planning.
Effectiveness	Sometimes highly accurate even from high altitudes, even against point targets; lower likelihood of collateral damage.	"One target, one bomb" is an inappropriate and illusive characterisation of LGB effectiveness; no consistent relationship between the use of guided munitions and targets that were successfully destroyed.

2.4.3 Munitions Cost and Performance

Guided munitions are many times more costly than unguided munitions and their deployment was constrained by poor weather, clouds, heavy smoke, dust, fog, haze and even humidity. However, guided munitions were less affected by winds and unlike unguided munitions, they had greater consistency from medium-to-high altitudes. Although relatively inexpensive and less restricted by adverse weather conditions, unguided munitions cannot be deployed reliably against point targets from the medium and high altitudes predominantly used in Desert Storm.

While guided munitions can be accurate from high altitude, their standoff capability does not necessarily protect them from defences not at the target. Even though they are clearly more accurate from medium-to-high altitudes, their high unit cost means that they may not be the least expensive way to attack certain targets.

3. Operation Allied Force

"The choice is truly up to the leadership on both sides, especially the authorities in Belgrade. Either they cease fighting and agree upon a peaceful interim settlement, or they will face the consequences NATO has spelled out today."

- Secretary of State Madeline K. Albright
January 30, 1999 [11]

3.1 The Campaign over Kosovo

At 1900 hours GMT on the 24th of March 1999, NATO forces began air operations over the Former Republic of Yugoslavia. NATO was prepared to suspend its air strikes once Belgrade unequivocally accepted its conditions and demonstrably began to withdraw its forces from Kosovo according to a precise and rapid timetable.

3.1.1 Campaign Objectives

At the outset of Operation Allied Force, NATO set specific strategic objectives for its use of force in Kosovo. After consistent refinement by the North Atlantic Council, they served as the basis for its stated conditions to Milosevic for cease-fire. These objectives were to [9]:

- Demonstrate the seriousness of NATO's opposition to Belgrade's aggression in the Balkans
- Deter Milosevic from continuing and escalating his attacks on helpless civilians and create conditions to reverse his ethnic cleansing
- Damage Serbia's capacity to wage war against Kosovo in the future or spread the war to neighbours by diminishing or degrading its ability to conduct military operations.

After the decision to further intensify the air campaign by expanding the target set to include a broader range of objectives, the alliance clearly outlined its conditions to end the operation. As proclaimed in the NATO Statement on Kosovo, President Milosevic had to [12]:

- Ensure a viable stop to all military action and the immediate ending of violence and repression in Kosovo
- Withdraw from Kosovo the Serbian military, police and paramilitary forces
- Agree to the stationing in Kosovo of an international military presence
- Agree to the unconditional and safe return of all refugees and displaced persons and unhindered access to them by humanitarian aid organisations; and
- Provide credible assurance of Serbian willingness to work based on the Rambouillet Accords in the establishment of a political framework agreement for Kosovo in conformity with international law and the Charter of the United Nations.

Operation Allied Force covered all together five phases [17].

Phase 0 - Air forces were shifted for the accommodation of practice flight operation to their operational airfields.

Phase 1 - Conduct limited air operations against designated military targets. This phase began with attacks on the IADS in the entire FRY.
Phase 2 - Attacks extended to the security forces infrastructure military in Kosovo and reinforcement forces.
Phase 3 - The expansion of air operations against a broader range of high-value military and security force target sets. Lastly,
Phase 4 - Redeploy forces as required.

The campaign proceeded along two simultaneous lines of operations. The first, the strategic attack against the IADs, C^2, VJ and MUP forces, military supply routes and the sustaining infrastructure and resources. The second, attack in Kosovo to degrade deployed military and to isolate and interdict with the Serbian forces there.

3.1.2 Asymmetric warfare

Operation Allied Force was not a conventional military conflict [9]. There was no direct clash of masses of military ground forces and Milosevic was unable to challenge superior allied military capabilities directly. The Serbian fielded forces were compelled to hide throughout most of the campaign. Their antiaircraft missile defences united to sustain their defence of the allied air campaign. Therefore, the campaign was fought chiefly by asymmetric means.

Asymmetric warfare is unconventional and seeks to drive the military dimension into the civil dimension to offset Western superiority in high technology. The tools of asymmetric warfare include protracted guerrilla war, urban terrorist action and the use of irregular militia forces. They are military tools that are difficult to find and extirpate quickly. The following are a few of the asymmetric tactics used by the Serbian/Yugoslav forces:

- The positioning of tanks and other military equipment in the middle of villages and in other locations where the Serbian/Yugoslav forces knew that the concern to minimise collateral damage would prevent the Coalition from targeting them
- Human Rights Watch and OSCE documented at least one case of the use of human shields
- Attacks against civilians
- Extensive disinformation/propaganda

In future, if potential adversaries consider themselves unable to oppose us by conventional means, they may increasingly rely on techniques such as those outlined.

3.2 Intelligence and Targeting Support

Intelligence and targeting support played a large and critical role in the success of Operation Allied Force. The principal accomplishments and lessons learnt regarding these assets and their deployment in Kosovo are discussed in this section.

3.2.1 Intelligence collection

Intelligence collection is necessary to support all military operations. In Operation Allied Force, two operational requirements made the effective and thorough collection of intelligence a high priority [9]:

1. The need to create a comprehensive picture of the battle space, and
2. The need to simultaneously detect and track elusive mobile targets.

Intelligence, surveillance and reconnaissance assets were in extremely high demand throughout the conflict. These platforms are critical for their multiple intelligence collection capabilities such as taking photographic or radar images, monitoring enemy communications and locating the sources of electronic signals.

The overall quality and level of intelligence support provided during Operation Allied Force was far superior to that provided in the Gulf War. However, some improvements can still be made in a rapidly changing world environment [9].

Dynamic targeting - This is the difficult challenge of rapidly targeting enemy forces that can move and hide frequently. Furthermore, there needs to be an emphasis on rapidly collecting and disseminating no-strike target information to avoid collateral damage.

Foliage and weather penetrating sensors - Detecting and tracking mobile targets on the ground in poor weather was still extremely difficult. In addition, future adversaries are expected to use concealment and deception to hide forces. Thus, the need arises for sensors that can be used in all weather and in foliage-covered terrain.

Geolocation accuracy and timeliness - Further improvement of ISR sensors and the targeting process is needed to be able to deploy precision munitions against fixed and mobile targets and to re-target those weapons dynamically.

Unmanned Aerial Vehicles were used for surveillance and reconnaissance, location and targeting Serbian military forces and to perform near-real-time BDA to allow timely re-strike and to cross-cue other ISR assets. Despite some problems, the application of UAVs in Kosovo clearly demonstrates their potential to become a highly flexible and effective ISR asset in future conflicts.

3.2.2 Precision Intelligence

Precision engagement consists of the following sequence of events [9]:

1. Accurate target location and identification;
2. Responsive command and control of strike forces;
3. Achievement of desired engagement effects on the target;
4. Assessment of the level of success of the engagement; and
5. Reengagement of the target with precision if desired.

In order to achieve precision engagement, precision intelligence is required. During Operation Allied Force, precision intelligence played a significant role in the deployment of precision munitions to systematically degrade important Serbian military targets.

A number of systems currently in research and development would have been useful had they been available. In fact, if nothing else, Operation Allied Force emphasized the need to continue on the modernization path that began after Desert Storm.

There is a need to field systems that improve precision and timeliness used to detect, identify, track, and assess potential targets, regardless of constraints imposed by adverse weather, nighttime, concealment and deception techniques, or rapid movement. Likewise, those areas that contribute to precision intelligence, dynamic collection management, common battle space awareness, and interoperable intelligence systems and architectures when fielded will all contribute to more effectiveness in conflicts such as this one. In addition, improved policies, procedures, and tools are needed to further enhance the quality and responsiveness of precision intelligence support for military operations. Areas that warrant particular emphasis based on experiences in Operation Allied Force are as follows:

- Preparation for crises and the transition-to-crisis by the Intelligence community;
- Development of collection strategies that concord national policy and theater operational requirements when necessary;
- Development of a mix of improved sensors with day and night, adverse weather capability to identify and track mobile targets with required timeliness and geolocation accuracy in the presence of sophisticated camouflage, concealment, and deception techniques;
- Inclusion of UAV sensor data and cockpit video into the tasking, processing, exploitation, and dissemination processes;
- Consideration of operational targeting needs when developing ISR system requirements
- Development of streamlined ways to exchange intelligence information (to include Web-based collaborative tools) between the intelligence communities and supported forces of the allied partners; and
- Continued development of capabilities to disseminate sensor data directly to in-theater tactical forces.

3.2.3 Effects of Weather and Countermeasures

Air operations were greatly affected by bad weather a significant portion of the time. Cloud cover was greater than 50 percent more than 70 percent of the time. Figure 5 demonstrates the extensive cloud cover that was often present in much of the theatre. These weather conditions allowed for unhindered air strikes on as few as 24 of the 78 days [9]. The key weather related observation relating to Operation Allied Force is therefore the need for all-weather search capabilities in target detection and tracking.

The Serbian forces in Kosovo employed camouflage, concealment and deception techniques extensively to protect themselves. While this reliance did achieve its aim – to protect the Serbian forces – it also precluded conventional manoeuvre operations and therefore limited their fighting effectiveness. The Serbian air defences also moved and hid a large amount of the time, which reduced their ability to hit NATO aircraft whilst increasing their survivability.

3.2.4 Lessons for Countering Serbian IADS

An important point to note is that the Serbian IADS did not represent the 'state-of-the-art'. Although many countries hold large quantities of such weapons, much more capable systems are available on the international market and in the future, there is a need to prepare for and expect adversaries to be armed with 'state-of-the-art' systems.

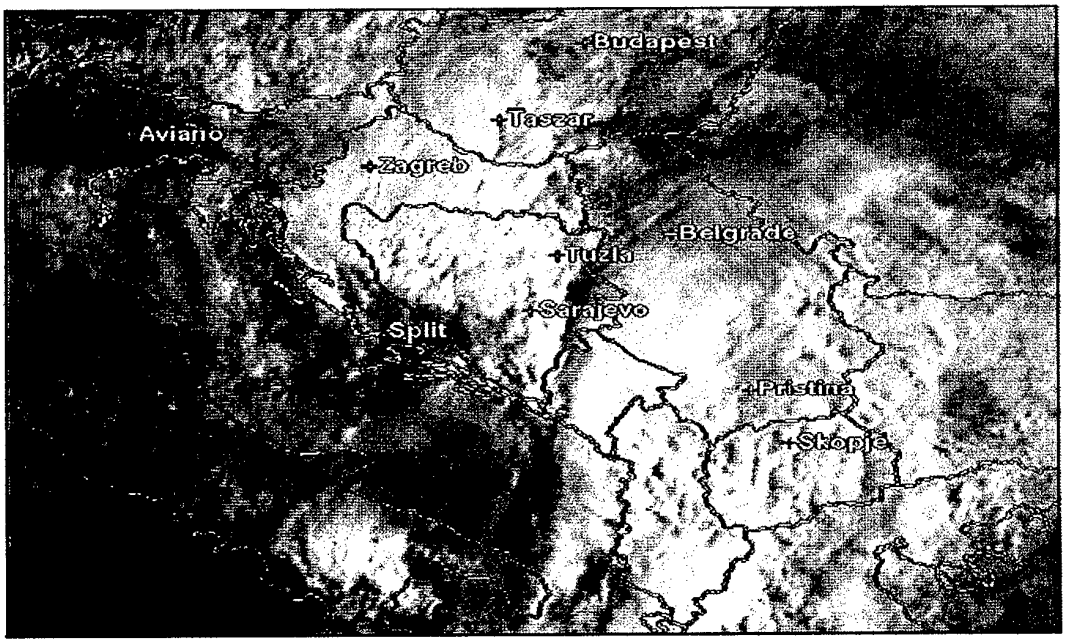

Figure 5: Satellite image of typical weather over Kosovo [9]

These systems include new weapons that do not have a legacy of being involved in past conflicts and make use of the latest technology.

In general, there is a need for continuous real-time precision location of passive and active enemy systems, which will enable allied forces to focus their efforts and achieve effective suppression and destruction of enemy weapon systems. The successful development of real-time sensor-to-shooter technology along with further enhancements of offensive and defensive night vision systems should also improve effectiveness.

3.3 Strike Operations

During Operation Allied Force, NATO forces conducted over 23,300 strike missions against an array of targets. These strikes were directed at roughly 7,600-target aim points associated with a variety of fixed targets as well as at just over 3,400 relocatable/mobile targets.

There are two notable aspects of strike operations performed in Kosovo.

1. Firstly, there was a greater use of standoff and GPS-guided munitions to attack targets throughout the FRY.
2. Secondly, the operation was marked by the introduction of new technology including B-52s equipped with Joint Direct Attack Munitions.

Adverse weather and rugged undeveloped terrain characterised the operating environment of Allied Force. This had a corresponding impact on the conduct of operations, including target selection and the pairings of weapons and delivery platforms.

Table 6: Characteristics of Weapons Used in Operation Allied Force [9]

Range	Guidance	Weapon Name	Specific Characteristics
Long	GPS (near precision)	CALCM	Air launched from B-52 Unitary Warhead Powered
Standoff (>15 miles)	INS/GPS (near precision)	SLAM	Air launched from P-3 Powered INS and GPS midcourse guidance
Standoff (>15 miles)	Man-in-the loop Terminal (precise)	AGM-130	Air launched from F-15E Unitary warhead Powered INS and GPS midcourse guidance
Standoff (>15 miles)	GPS (near precision)	JSOW	Air launched from F/A-18 CEB sub munition dispenser Unpowered
Standoff (>15 miles)	Man-in-the loop Terminal (precise)	HAVE NAP	Air launched from B-52 Blast fragmentation or penetrator warhead Powered Inertial midcourse guidance
Direct Attack	GPS (near precision)	JDAM	Air launched from B-2 Low cost ($18K) tail kit Blast fragmentation or penetrator warhead
Direct Attack	GPS (near precision)	GBU-37	Air launched from B-2 Very hard-target penetrator with GPS tail kit
Direct Attack	Man-in-the loop (precise)	Maverick	Shaped charge or unitary warhead
Direct Attack	Man-in-the loop Laser Guided Bombs (precise)	GBU-10 12 16 24 27 28	Blast fragmentation Blast fragmentation Blast fragmentation Blast fragmentation Penetrator Very hard-target penetrator

The majority of direct attack weapons deployed during Allied Force were LGBs. In addition, long-range standoff munitions such as the Tomahawk Land Attack Missile and the Conventional Air Launched Cruise Missile were deployed extensively, especially during the initial stages of the operation and in adverse weather conditions. Details of the PGMs used during operations in Kosovo are shown in Table 6 [9].

Despite the considerable utility of PGMs, there remains an effective role for non-guided munitions. Particularly if the location of the aircraft can be verified by use of GPS systems, a non-guided bomb can be dropped with considerable accuracy on carefully chosen targets.

BDA and the evaluation of the effectiveness of allied attacks against various targets in Serbia and Kosovo remained at the forefront of NATO efforts and concerns. While wartime BDA did not always provide complete information, wartime assessments of damage to fixed targets in Kosovo were generally accurate [9]. However, Serbia's VJ and MUP forces presented a targeting and damage assessment challenge.

3.3.1 Strike Effectiveness

The inability of NATOs precision air munitions to locate and destroy a passive, well-dispersed and concealed Serbian ground force was the major weakness of the air campaign.

Air attack operations were designed to accomplish specific objectives. In turn, targets were selected with the goal of attaining these objectives in a phased operation. Analyses

of the results of NATO attacks were based on the fullest available information. Analysts used imagery and other sources to review the desired impact points to assess the damage done by each strike sortie. Time sequencing between strike sorties and reconnaissance of an impact point were critical. After the conflict, NATO sent a team into Kosovo to assess the effects of air attacks against both fixed and mobile targets.

3.3.1.1 Fixed Targets

Following the end of Operations in Kosovo, NATO released an initial assessment of attack effectiveness against a number of targets. The targets that were destroyed or significantly damaged included:

- Eleven railroad bridges
- Thirty-four highway bridges
- Twenty-nine percent of all Serbian ammunition storage
- Fifty-seven percent of petroleum reserves
- All Yugoslav oil refineries
- Fourteen command posts
- Over one hundred aircraft and
- Ten military airfields

After the bombing campaign had ended, an assessment team [9] from NATO visited a representative sample of fixed targets. Based on the observations of target characteristics, physical and functional target damage, weapon impact locations and effectiveness and evidence of collateral damage, the team assessed strike effectiveness against fixed targets.

NATO attacks against tunnels, bunkers and bridges were all found to be successful, with attacks against tunnels producing greater than expected results. Attacks against above ground structures include garrisons and headquarters structures were also successful. Overall NATO's effort against such structures was a complete success, severely damaging structures with minimal collateral damage.

Throughout the air operation against the Serbs NATO made every effort to minimize collateral damage. Of the 38 sites visited by the assessment team, only one had significant collateral damage from NATO weapons falling on areas other than their intended target. At the other sites, collateral damage was limited to broken windows, blown off roof tiles and detached ceiling tiles.

3.3.1.2 Mobile Targets

Although there were still problems with locating and destroying mobile systems, by the time that bombing was suspended the officials thought they had destroyed considerable amounts of artillery and armoured vehicles and were starting to consistently hit Serbian tanks.

The assessment of the number of mobile targets struck during operations was achieved by conducting a comprehensive reconstruction of the operation – day-by-day, mission-report-by-mission-report – to determine the actual number of mobile targets struck with high confidence. This was achieved by a NATO team sent into Kosovo [9].

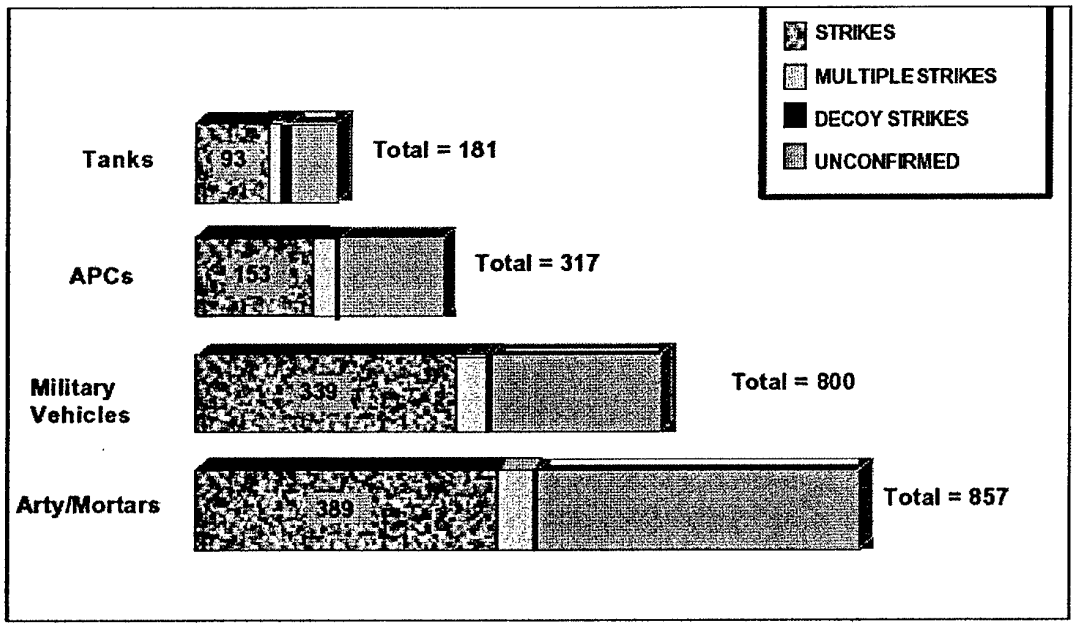

Figure 6: Strike assessment results on mobile targets [9]

The assessment does not provide proportional data on the total mobile targets hit or the level of damage inflicted on the targets struck. Instead, the numbers of target hits were collated. Thus, in the following figure (Figure 6 [9]), the first part of each bar represents the total number of strikes that achieved successful hits against mobile targets. The last segment of each bar represents those mission reports that provided sufficient evidence of a hit based on the methodology to support a successful strike assessment. These targets represent possible hits that cannot be confirmed. The team also assessed a small number of targets that had been hit by multiple strike missions and a more limited number of decoy targets that had been attacked.

3.3.2 Preferred Munitions

The latest generation of air-delivered PGMs were deployed in substantial numbers for the first time during Allied Force. Throughout the conflict, weapons fired at fixed sites hit intended targets producing intended results, with limited collateral damage to civilians. In particular, the success achieved in delivering the JDAM from altitudes above cloud cover demonstrated the wisdom of decisions made following the 1991 Gulf War.

As expected, attacks on mobile targets proved more problematic than attacks against fixed targets. The Serbs hid many of their mobile assets making them difficult (relatively impossible) to locate and attack. Another constraint was the desire to limit collateral damage, which in some circumstances prevented attacks on possible ground force targets.

3.3.2.1 Precision Engagement

Guided munitions were designated into two categories in Operation Allied Force: man-in-the-loop and GPS guidance. Typically, man-in-the-loop guidance requires line of sight from the sensor to the target (LGBs), these weapons are degraded by adverse

weather conditions. GPS guided munitions use satellite input to track specific target coordinates, which makes the weapon capable of all-weather deployment.

Allied Force also demonstrated the importance of Combined Effects Munitions. These munitions are soft drink-can-sized bomblet sub munitions, designated BLU-97 or cluster bombs. They can be dispensed by several different airframes including the:

- TLAM-D from long-range
- JSOW from medium-standoff range and
- CBU-87 tactical munitions dispenser for direct attack.

The CEM is an effective weapon against air defence radars, armour, artillery and personnel. However, there is an unexploded ordnance hazard associated with this weapon and they may explode if disturbed or disassembled.

The requirement of a mix of weapon capabilities and platforms was again highlighted in Operation Allied Force. In the final stages of the campaign, direct attack munitions could be deployed at less risk and therefore in many cases relatively "dumb" bombs were as effective as more costly preferred munitions against large area targets.

3.3.3 Weapons of Choice

Cruise missiles were used extensively in the first days of the operation as well as in periods of adverse weather conditions. As the conflict continued, a larger cross-section of the weapons inventory was deployed, including standoff, GPS-guided, laser-guided and unguided bombs. GPS guided systems were critical to the success of the campaign due to the weather and the requirement for limited collateral damage.

PGMs in Allied Force represented only 35 percent of the ground-attack weapons used, but accounted for 74 percent of the targets destroyed. The ability to perform all weather strikes was limited, but the performance of the B-52 bomber combined with the JDAM became an effective counter to these limitations. CALCMs were also deployed with great effect – principally against infrastructure targets like power plants, and command and control nodes.

3.3.4 Insights and Observations

"Preliminary and follow-up ground battle damage assessments show that fuse setting can be a critical factor in the amount of damage inflicted. Effective real-time targeting may require that aircraft have the capability to change weapon fuse settings while airborne. This would allow the aircrew to maximize target destruction while adjusting for specific collateral damage restrictions." [9]

Attacking time sensitive targets is a long standing military requirement. The need for rapid targeting and retargeting of aircraft and preferred munitions against known and emerging targets was again validated throughout this conflict.

The lessons learned in the area of precision engagement lead to the following set of observations:

- Replenish inventories of PGMs and continue to assess development of weapons that fill gaps and shortfalls in current capabilities and their subsequent certification on launch platforms.
- Assess methods to determine wartime planning factors affecting expenditure rates.
- Assess future weapon inventories to achieve the right balance of capabilities for future requirements.
- Continue to assess technologies that will ensure flexibility and enable all-weather precision strikes, including accurate targeting capability against fixed and mobile targets that can be executed within minutes of target assignment.
- Continue to pursue technologies that will process, exploit and disseminate target data in a timely manner to support precision engagement.
- Enhance the level of detail and quality of intelligence to support theatre-wide GPS targeting requirements, especially in real or near-real time.

3.3.5 Effects of Weather on Strike Operations

Air operations and strike execution were impacted by the requirement for favourable weather in up to four geographically dispersed locations. These were the:

1. Target area,
2. Base from which the strike aircraft were operating,
3. Base used by any aircraft supporting the strike and
4. Orbit location for the refuelling tankers.

This requirement complicates strike execution by allowing brief, localised periods of adverse weather to negatively affect overall operations. At the beginning of the operation, the weather was so poor that NATO could operate against fielded forces only about 15% of the time [17]. Numerous examples exist of cancellations of strike missions due to inclement weather, which makes it clear why the capability to accurately forecast weather conditions is so valuable. As mentioned earlier the weather conditions over Kosovo hampered the ability to deploy LGBs and put a premium on other PGMs.

3.4 Summary

Below is a summary of the findings on Operation Allied Force carried out in Kosovo and Serbia proper. Unfortunately, the amount of information regarding this conflict is limited. As seen below, there are no quantitative conclusions regarding weapon numbers. In general, this is because of the need for concrete information, which was unavailable.

3.4.1 Intelligence and Targeting Support

The overall level of ISR support given during Operation Allied Force was far superior to that provided during Operation Desert Storm. Many of the system and architecture shortfalls that surfaced during Desert Storm have been recognised and cures programmed. Others however, became evident for the first time.

a) Enhance the deployment of ISR assets so as to provide adequate support for emergent theatre level requirements whilst maintaining required levels of surveillance and intelligence awareness worldwide.

b) Improve ISR sensors and communications capability to improve the ability to target adversary's mobile-fielded forces. There is also a need to emphasise rapid collection and dissemination of no-strike target information to avoid collateral damage.
c) Improve the capability to use UAVs and to better integrate these systems in overall campaign plans.
d) Improve the capability to provide precision intelligence.
e) Improve the ability to counter an adversary's use of camouflage, concealment and deception. More emphasis should be placed on the development of advanced sensors and improved training
f) Enhance capability to locate and attack air defence threats.

3.4.2 Target Attack

Allied Force was notable for its heavy reliance on standoff and PGMs to attack targets and by the successful introduction of new strike platforms and weapons. The campaign was, in the main, primarily and successfully implemented by systems and platforms that have long been in the inventory. The following points are relevant as lessons on target attack:

i. Enhance precision engagement capability by assessing technologies that will ensure flexibility and enable all-weather capability in precision strike. In addition, pursue technologies that will process, exploit and disseminate target data in a timely manner to support precision engagement.
ii. Enhance the capability to use preferred munitions by:
   - Replenishing inventories of preferred munitions.
   - Assess development of weapons that fill gaps and shortfalls in current capabilities.
   - Assess future weapon inventories to achieve the proper balance of capabilities for upcoming requirements.

3.4.3 Improvements Achieved

Although quantitative information about this conflict is not as available as for Desert Storm, there can be some relevant points extracted on the differences between the two.

- The notable reliance on standoff and PGMs in Allied Force is in direct contrast to Desert Storm, where the majority of weapons used were considered "dumb" bombs.
- LGBs were not used as frequently, most probably due to the lessons learnt from Desert Storm. Another possibility is that the infrequent use of LGBs was due to the weather conditions experienced throughout the conflict.
- The use of ISR assets decreased the sensor-to-shooter loop to hours instead of the days seen in Desert Storm.
- Some enhanced capability was seen for the use of PGMs in adverse weather conditions. More enhancements are needed in these areas, although improvement was achieved in the time between Desert Storm and Allied Force.

4. Operation Enduring Freedom

"The attack took place on American soil, but it was an attack on the heart and soul of the civilised world. And the world has come together to fight a new and different war, the first and we hope the only one of the 21st Century. A war against all those who seek to export terror and a war against those governments that support or shelter them."

- President George W. Bush
11th October 2001[11]

4.1 The Military Campaign

Operation Enduring Freedom began on October 7, 2001. The enemy was not a nation - the enemy was terrorist networks that threaten the way of life of all peaceful people.

The Coalition achieved broad military success by adapting quickly to the distant, harsh and ever-changing battlefield. In some cases, US troops conquered terrorists by welding 21st Century technology with 19th Century tactics. Troops chased terrorists on horseback while using mobile phones and GPS to pinpoint targets for the air force.

A few of the key military successes achieved so far include [14]:

- The military essentially destroyed al-Qaeda's grip on Afghanistan by driving the Taliban from power.
- Taliban leaders have surrendered major cities to opposition forces.
- The military has destroyed at least eleven terrorist training camps and thirty-nine Taliban C^2 sites.
- About 2.5 million humanitarian rations have been dropped to aid the people of Afghanistan.
- US Marines have established a military base at Kandahar airport.
- Routes have been blocked to try to prevent the escape of al-Qaeda and Taliban members.
- Senior al-Qaeda and Taliban officials have either been captured or killed.
- US military rescued two American Christian aid workers who were being held as prisoners by the Taliban.
- Friendship Bridge was reopened to transport humanitarian air by land.
- Minefields and roads have been cleared to endure delivery of aid and freedom of movement.

4.2 First Lessons

The US led military campaign in Afghanistan was the war that the US Department of Defence had been planning. This war has featured improvements and the progression of trends based on the lessons learnt in the 1991 Gulf War and 1999s Operation Allied Force in Kosovo.

The military campaign has relied heavily on airpower capability, much like in Kosovo, but improved ISR and networking capabilities have proven to be vital. However, despite the swift military success in Afghanistan, the operation also struggled with a low-tech asymmetric enemy. As in Kosovo, enemy forces sought to evade US airpower by

dispersing and concealing equipment and troops – this time among the civilian population, religious sites or in caves.

The introduction of Special Operations Forces and intelligence personnel on the ground has provided real or near-real time targeting data – with the use of laser designators or by calling in GPS coordinates either through radios or laptops to US aircraft flying overhead. This insertion of SOF units enabled US strikes to move from primarily fixed targets to Taliban frontline forces. "You could just see the change in effectiveness of the bombing," Defence Secretary Donald Rumsfeld said on 7 December of the effect the insertion of SOF with anti-Taliban forces had on the campaign.

Still, there were problems when opportunities to strike high-value but time-critical targets were missed in the first few weeks of the war. This problem was attributed to the length of the decision loop – the time required from when a sensor detects a target to when it can be identified and approved by a human operator. These problems first surfaced in previous wars in the Gulf and Kosovo, although the sensor-to-shooter loop has been tightened from days to hours and now minutes.

In addition, there is a genuine need for US/Western tactical aircraft to be equipped with digital satellite communications equipment. Currently the aircraft rely on the AWACS to send messages to other aircraft and ground forces out of range. The general need for an integrated seamless network of information will form the backbone of future network centric warfare.

Locating and striking hard and deeply buried targets has also been one of the more challenging issues. For years, this has been one of the most difficult tasks, yet to be answered, but investment is still being made into the area. In Afghanistan, two primary weapons were used to combat this problem. The GBU-28 "Bunker Buster" to penetrate hardened bunkers, and AGM-130s fired into the mouths of caves to seal them off.

4.2.1 The Information Revolution

A clear picture of the battlefield, shared across the all the platforms and fighting forces, is required to achieve the maximum potential of precision guided munitions and high-tech weaponry. Such information enhances both the rate of accuracy in targeting and meeting obligations under the laws of armed conflict. The new technologies and techniques employed in Afghanistan were intended to inform the US and Allied forces, not to extirpate.

Seamless transfers of information-sharing capabilities have long been sort after and are beginning to take place. The transfer of battlefield information from one platform to another (including space assets) proved particularly useful in enabling attack aircraft to strike targets of opportunity such as troop formations or convoys of Taliban and al-Qaeda leaders.

DoD sources [13] say that the Pentagon is working to close the sensor-to shooter timeline to 10 minutes, which would allow forces to strike most mobile targets. In addition, the US has greatly improved the accuracy and speed of BDAs, partly due to investments in data fusion made after the Gulf War.

As of April 2002, more than 22,000 bombs and missiles had been dropped on Afghanistan. Military officials say that about 75 percent hit their targets and probably destroyed or disabled them. Precision-guided munitions made up 60 percent of all weapons and their effectiveness was about 90 percent [14].

The precision guided munitions included GBU-31 JDAMs, AGM-130s and LGBs. The US Navy states that 80 percent of sorties hit targets; 84 percent of strikers who dropped ordnance hit at least 1 target; and PGMs constituted 93 percent of the ordnance dropped. In addition, 80 percent of the sorties that delivered ordnance did so against a target that was unknown to the pilots when they landed [14].

Even the accuracy of "dumb" bombs has improved with more accurate aircraft radars and better computers that gauge the ballistics of weapons.

Vice Admiral John Natham, Commander, Naval Air Force, US Pacific Fleet detailed that, "Afghanistan was the complete opposite from what happened in Desert Storm, where the Navy averaged 10 aircraft per target...In Afghanistan, there were two targets per aircraft" [14].

The most commonly used munition in the war was the JDAM. The JDAMs "accuracy has proven to be, again, remarkably good and remarkably consistent" in the Afghan campaign, said General John Jumper, USAF Chief of Staff. The Afghanistan conflict has also marked the first operational use of the Wind Corrected Munitions Dispenser (WCMD), which was developed to help control the spread pattern of cluster bombs. Gen Jumper said that these weapons had been "highly successful" [14].

4.3 Summary

There are very few details known about Operation Enduring Freedom, therefore it is difficult to draw conclusions and learn lessons on the use of precision weapons. The fact that the accuracy of PGMs and the level of information technology used have increased since previous conflicts shows that the majority of lessons learnt from those conflicts have been implemented and used effectively.

4.3.1 Key Lessons

Some of the main points that need to be highlighted are:

- The improved ISR and networking capabilities have proven to be vital
- A clear picture of the battlefield, shared across the all the platforms and fighting forces, is required to achieve the maximum potential of precision guided munitions and high-tech weaponry. Such information enhances both the rate of accuracy in targeting and meeting obligations under the laws of armed conflict.
- The general need for an integrated seamless network of information will form the backbone of future network centric warfare.

4.3.2 Improvements Achieved

Although a distinct lack of information is available at present on the conflict in Afghanistan, some achievements have been made by implementing lessons learnt from previous conflicts. These are highlighted below:

- The improvements to ISR capabilities have decreased the sensor-to-shooter timeline from days in Desert Storm, to hours in Allied Force, and minutes in Enduring Freedom.
- Network centric warfare is the key to future battles. As explained, a clear picture of the battlefield is needed and that knowledge must be shared between platforms and fighting forces. This has not been seen previously, although the introduction of ISR assets in Allied Force would have enabled some effort toward network centric warfare, it has become of prominent interest in today's battle scenarios.
- Asymmetric warfare techniques carried through from Allied Force to Afghanistan, where the enemy is no longer large and well equipped but is sparse and well hidden.

5. Lessons

A majority of the lessons that can be learnt from conflicts in the past decade have already been implemented by forces in the US and UK. The main objectives listed at the beginning of this report will be discussed in this section in relation to the lessons learnt from the conflicts discussed.

5.1 General Lessons Learnt

This section covers the lessons that were learnt by other countries in relation to the major objectives of this report.

5.1.1 Intelligence Support & Operations Planning

- Significant need for high levels of information regarding the battle space.
- Increasing need for more intelligent Unmanned Aerial Vehicles concomitant with an increase in their sensor and communications capabilities.
- Improve the capability to provide precision intelligence.

5.1.2 Time Critical Targeting

- Continue to decrease the sensor-to-shooter loop so that targeting and destroying mobile targets is an accessible option.
- Increase the level and timeliness of BDA providing accurate information to pilots.

5.1.3 Effects of Weather & Countermeasures

- Aircraft targeting capabilities and PGMs are put to the test by periods of adverse weather as well as adverse conditions, such as smoke from oil fires, or dust from bombing.
- Even some of the milder weather conditions, including humidity, render precision bombing IR and EO sensors either degraded or inoperable.
- Execution of air operations is impacted by the requirement for favourable weather in up to four geographically disperse locations. Namely, the target area, the base from which the strike aircraft were operating, the base used by any supporting aircraft and the orbit location of the refuelling tankers.
- IR and EO systems are impeded by environmental conditions. EO systems have proven to be at least as vulnerable to degradation as other sensors and lack fulltime night capability.
- The weather conditions over Kosovo hampered the ability to deploy LGBs and put a premium on other PGMs.
- Improve the ability to counter an adversary's use of camouflage, concealment and deception tactics.
- Enhance the capability to locate and extirpate air defence threats.

5.1.4 Weapon use & Effectiveness Analysis

- The claim for LGBs summarised by "one target, one bomb" was proven incorrect in Desert Storm
- Of 167 LGBs dropped, 76 (45.5 percent) missed their targets in 1991.
- Plan for and expect use of munitions from higher altitudes and outside of the range of enemy air defences. From experiences in Desert Storm, accuracy of unguided weapons is greatly reduced at medium to high altitude deliveries.
- Whilst guided munitions can be more accurate from higher altitudes than unguided, their standoff capability does not necessarily protect the weapon from defences not at the target.
- Guided munitions are many times more costly than unguided, and their deployment is constrained by poor weather, clouds, smoke, dust, fog, haze and even humidity. Even though their deployment at medium to high altitudes in Desert Storm was clearly more accurate, their high unit cost means that they may not be the least expensive way to attack certain targets.

5.1.5 Timely Combat Assessment

- Few assertions about the Gulf War could command as much agreement as the inadequacy of Battle Damage Assessment.
- In Desert Storm, reports from US AF, Navy and Marine flight crewmembers and those of other Coalition air forces agreed that they received little or no BDA on the targets they attacked during the entire war.
- Unmanned Aerial Vehicles were used in Allied Force for surveillance and reconnaissance, location and targeting Serbian military forces and to perform near-real-time BDA to allow timely re-strike and to cross-cue other ISR assets. This is one of the main improvements implemented after Desert Storm. Although the sensor-to-shooter timeline was shortened to hours, the high level of PGM use required more improvement from the BDA process.
- The Pentagon is currently (during Operation Enduring Freedom), working to close the sensor-to shooter timeline to 10 minutes, which would allow forces to strike most mobile targets. In addition, the US has greatly improved the accuracy and speed of BDAs, partly due to investments in data fusion made after the Gulf War.

5.2 Relevance to the ADF

This section covers the lessons that are currently important to the ADF and the relevance the above lessons have to the defence of Australia. These considerations are based on the following points:

1. The ADF cannot maintain a high operational tempo, so every strike package/mission must count.
2. The ADF cannot afford aircraft losses during most scenarios (unless the scenario is a no holds barred defence of Australia).
3. There are limitations/considerations in relation to the ADFs intelligence and targeting support capabilities.

The above points are not exhausted in relation to the ADFs capabilities, but they will be discussed relative to the above lessons.

- Intelligence support and operations planning - precision weaponry requires precision intelligence. The current tempo of operations requires significant information regarding the battle space, and smarter ISR assets, coupled with an increase in their sensor and communications capabilities. The lessons for the ADF here pertain to the affordability of such weapons, in an attempt to enable this higher tempo of operations.
- Time critical targeting - To achieve this level of targeting capability a decrease in the sensor-to-shooter loop is needed. Currently, the loop is being closed to around 10 minutes by the US, which they believe is viable for today's mobile and relocatable targets. This affects the ADF on all levels; there are limitations in relation to the ADFs intelligence and targeting support capabilities; and there is a requirement for a high operational tempo, where network centric warfare is the possible key to success.
- Effects of weather and countermeasures - adverse weather is one of the main problems relating to the use of precision weaponry. The ADF must consider its financial position when using PGMs and therefore should have distinct preferences toward those weapons whose sensors are not affected by the adverse weather conditions predominant in many battle space environments. The enemy's use of countermeasures and camouflage are also an important consideration when deploying PGMs. Assurances need to be made on the correct identification, recognition and acquisition of targets. The ADF cannot afford to deploy munitions on a false target and therefore should take care in its targeting capabilities.
- Weapon use and effectiveness - the incorrect "one target, one bomb" claim for LGBs is an important statement for the ADF as its current stockpile includes such weapons. When the decision to strike using a certain weapon is made, this lesson must be taken into account in the process of determining the cost of the strike and the survivability of the strike and laser designator platforms.
- Timely combat assessment - the work to improve the sensor-to-shooter timeline is extremely important to the ADF because of the need to provide accurate information about the battle space to all of the necessary platforms and command personnel. The accuracy and timeliness of information has the ability to decrease the costs that exist due to extra strikes being made on targets that have already been destroyed.

5.3 Future Considerations

Although it is difficult to predict the future, we can see the evolving nature of warfare through this small snapshot of time.

The war fighting techniques used by the enemy are significantly more asymmetric in nature, which will increase as time continues. This increase in asymmetric warfare will come in a time where collateral damage is an important consideration for all nations. The introduction of on-the-spot news teams increases the need to be more precise in the identification, recognition and acquisition of targets. These points indicate that the use of precision munitions will increase concomitantly with a decrease in the sensor-to-shooter timeline. ISR assets will become increasingly more important to the ADF as the enemies mobility and sparse dispersion becomes more predominant. Furthermore, network centric warfare will present itself as an important tool in tomorrow's high tempo operational environment.

As precision guided technologies increase in their level of reliability and accuracy, the degree of technology used to counter these munitions (e.g. IADS) will increase concurrently. It is now up to the ADF to stay abreast of this continual cycle of technology enhancement.

Appendix A: Timeline

[5] [15] [16][17]

1967	AGM-62 Walleye first fielded
1972	Air force accepts first AGM-65 Maverick
1976	First capability for GBU-12 LGB
1982	December: AGM-86B ALCMs become operational
1983	First operational capability for the GBU-15 & GBU-24
1986	June: First ALCMs converted to AGM-86C CALCMs
1990	August 2: Iraq invades Kuwait
	August 7: Operation Desert Shield begins
1991	First capability for the GBU-28 "bunker buster"
	January 15: Desert Shield ends as deadline for peace passes
	January 16: Operation Desert Storm begins
	February 24: Allied ground assault begins
	February 27: Cessation of hostilities declared
	March 1: Cease-fire terms negotiated
	April 11: Saddam Hussein agrees to UN Security Council terms and conflict declared officially over
1992	First AGM-142 capability
1997	June: JDAM certified as operational capable
1998	October 13: Phase 0 of Allied Force initiated authorising for both "limited air strikes" and a "phased air campaign" should Yugoslav authorities refuse to comply with the UN resolution
	October 15: Milosevic signs agreement committed to cease hostilities and withdraw mobilised forces in Kosovo
	November: WCMD limited initial operational capability achieved on the B-52
1999	March 24: Operation Allied Force begins (initial attack) Phase 1 - Establish air superiority over Kosovo
	March 27: Phase 2 - Attack military targets and those Yugoslav forces south of 44 degrees north latitude
	April 22: Alliance leaders decided to further intensify the air campaign by expanding the target set
	May 27: Milosevic and four other Serbian leaders were indicted by the UN War Crimes Tribunal for crimes against humanity
	June 10: Suspension of NATO air strikes
	June 13: UN High Commissioner for Refugees relief missions begin
	June 20: Serbian forces completely withdraw from Kosovo, leading NATO Secretary General Solana to officially end NATO's bombing campaign in the Federal Republic of Yugoslavia
2001	September 11: Terrorists attack freedom in the United States by destroying the World Trade Centre and wounding the Pentagon
	October 7: Operation Enduring Freedom begins and enjoys the support of countries from the United Kingdom to Australia to Japan
	November 6: Washington Post reports that the Taliban actually placed military assets in mosques and across the street from hospitals and innocent people's homes

Appendix B: Technologies

[18]

Operation	Technology
Desert Storm/Shield [19]	Space support: - 3D GPS 20 hours a day - 2D GPS 24 hours a day Intelligence Systems: - Mission Support System reduced mission preparation time to 4 hours rather than days needed in Vietnam. - Tactical digital facsimile provided the capability to send high-resolution pictures and data vital to combat success. - 3 Airborne Warning And Control Systems (AWACS) were continuously airborne controlling more than 3,000 Coalition sorties each day. - 2 Joint-STARS E-8's flew over 54 combat sorties although they were still in development. They tracked every vehicle that moved on the ground. Combat strike aircraft: - F-15E Strike Eagle is especially configured for deep strike missions to attack high value targets with a variety of munitions. Using LANTIRN technology the F-15E hit primary targets of C^2 centres, armour, electrical facilities, Scuds and road interdiction. - A-10 Thunderbolt II's fired 90 percent of the PG Maverick missiles launched during Desert Storm. - F-117 Stealth Fighters attacked the most heavily fortified targets during this Operation and were the only aircraft to bomb valuable strategic targets in downtown Baghdad and did so whilst limiting collateral damage. - B-52 Stratofortress were used to bomb airfields, industrial targets and storage areas in Iraq. During Desert Storm B-52s delivered 40 percent of all the weapons dropped by the Coalition forces. - F-111F used FLIR and laser designation systems to attack chemical, biological and nuclear sites as well as airfields, bunkers, C^3 facilities and parts of the IADS. - F-16 Fighting Falcon proved itself to be a very versatile day/night, good/bad weather aircraft. 249 F-16s flew more than 13,450 sorties - more than any other aircraft in the war. - AH-64D Apache is the Army's primary attack helicopter. It fires the AGM-114 Hellfire missiles and is principally involved in the destruction of high-value targets. Munitions (PGMs underlined): - GBU-12 LGBs deployed by F-111s. - GBU-15 electro-optical glide bombs were also used by F-111s to destroy oil manifolds. - GBU-24 LGBs were used by F-117s to hit hard targets such as aircraft shelters. - GBU-28 "Bunker Buster" dropped by F-111Fs in Desert Storm (two only). One weapon hit its precise aim point. - AGM-65 Mavericks were deployed by the F-16 and A-10 aircraft to attack armoured targets. According to the air force, during Desert Storm Maverick hit 85 percent of its targets. - BLU-82 dropped from special operations C-130s (eleven dropped). Initially the dropping of bombs was to test their mine clearing capability where no accurate BDA exists on effectiveness. Later, their psychological results were considered greater than their antipersonnel effects. - CBU-87 Combined Effects Munition (CEM) is used for attacking soft target areas with detonating bomblets. During Desert Storm, the USAF dropped 10,035 CBU-87's. - CBU-89 Gator Mine is a 1000-pound cluster munition containing anti-tank and antipersonnel mines. The USAF deployed 1,105 of these munitions during this Operation. - AGM-114 Hellfire is deployed by the AH-64 Apache Helicopter in a variety of modes. The one problem found during this conflict was the laser obscurant/backscatter. - AGM-62 Walleye is a guided glide bomb unit designed for delivery on a surface target by an attack aircraft. The requirement for visual contrast between the target and its immediate surroundings imposed problems during Desert Storm. For delivery, F/A-18 pilots reported that a target was sometimes indistinguishable from its own shadow. - AGM-86C CALCM developed to increase the effectiveness of B-52H bombers. There were 35 missiles launched during Desert Storm against high-priority targets in Iraq.

Operation Allied Force [3]	Space Support: - 3D GPS 24 hours a day Combat Strike Aircraft: - F-15E Strike Eagle air-to-ground attack aircraft is especially configured for deep strike missions. They are equipped with LANTIRN technology enhancing night PGM delivery capability. - F-16 Fighting Falcon, compact, multi-role fighter is highly manoeuvrable and has proven itself in combat and attack. - F-117 Nighthawk was the worlds first operational aircraft designed to exploit low-observable stealth technology. F-117's participated in air strikes against targets in the Balkans during NATO operations. - B-52 BUFF [Big Ugly Fat Fellow] heavy bomber is the primary nuclear bomber in the US inventory. It provides the only air-launched cruise missile in the USAF and can carry the AGM-142 and AGM-84 munitions. There was possible use of WCMD and JDAM from this aircraft in Allied Force. - B-1B Lancer long-range, multi-role, heavy bomber is capable of flying intercontinental missions without refuelling. It was upgraded to carry the Mk-82/62, CBU-87/89/97 and possibly JDAM for this Operation. - B-2 Spirit multi-role, heavy bomber is capable of delivering both nuclear and conventional munitions. It's most probable munition loads were the Mk-82/62, CBU-87/89/97 and possibly JDAM/Mk-84, JSOW and the GBU-37. Munitions (PGMs underlined): - CBU-87 CEM is used for attacking soft target areas with detonating bomblets. In Allied Force, the US dropped about 1,100 cluster bombs, most of which were the CBU-87. The dud rate for a standard cluster was approximately 5 percent. - JDAM is a tail kit, which produces a weapon with high accuracy, all-weather, autonomous, conventional bombing capability. It was the only all-weather capable munition deployed during this Operation. - AGM-86C CALCMs used by NATO in the bombing of Serbia primarily against Serbian air defences. - AGM-142 Provides the USAF B-52 with a precision man-in-the-loop capability to attack high-value, fixed targets from standoff ranges. This was the first precision capability for the B-52 bomber.
Operation Enduring Freedom [20]	Used Systems Strike Aircraft: - AH-64 Apache attack helicopters principle mission is the destruction of high value targets with the Hellfire laser designated missile - F-16 Fighting Falcon is a compact, multi-role fighter aircraft proven in both air-to-air combat and air-to-surface attack - F/A-18 Hornet fills a variety of roles: air superiority, fighter escort, suppression of enemy air defences, reconnaissance, forward air control, close and deep air support and day and night strike missions. - A-10/OA-10 Thunderbolt II can be used against all ground targets, including tanks and other armoured vehicles - B-1B Lancer is a multi-role, long-range bomber capable of flying intercontinental missions without refuelling, then penetrating present and predicted sophisticated enemy defences - B-2 Spirit is a multi-role bomber capable of delivering both conventional and nuclear munitions - B-52H BUFF is the primary nuclear role bomber in the USAF inventory. In a conventional conflict, the B-52 can perform air interdiction, offensive counter-air and maritime operations. Munitions (PGMs underlined): - AGM-142 is a medium range conventional stand-off missile providing the Air Force with a precision man-in-the-loop capability for the B-52H to attack high value, fixed targets from standoff ranges - AGM-114 Hellfire provides heavy anti-armour capability for attack helicopters - JDAM is a tail kit to produce a weapon with high accuracy, all-weather, autonomous, conventional bombing capability. JDAM will upgrade the existing inventory of general purpose and penetrator unitary bombs - GBU-28 Bunker Buster is a special weapon developed for penetrating hardened Iraqi command centres located deep underground - BLU-82 "Daisy Cutter" delivered from an MC-130 platform and used as an anti-personnel and intimidation weapon because of its very large lethal radius. It is the largest conventional bomb in existence. - CBU-87 Cluster bomb is a 1000-pound combined effects munition fro attacking soft target areas with detonating bomblets - CBU-89 Gator Mine is a 1000-pound cluster munition containing antitank and antipersonnel mines. The system provides a means to emplace minefields on the ground rapidly using a high-speed tactical aircraft.

	- Wind Corrected Munitions Dispenser (WCMD) Corrects for wind effects and errors during a weapons ballistic fall. It remedies the current shortfalls in Tactical Munition Dispenser arsenal (e.g. CBU-87/89). These weapons will be capable of delivery from medium to high altitude delivery when equipped with a WCMD kit. Potentially used systems PGMs: - AGM-88 HARM - AGM-86C CALCM

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1. PRIVACY MARKING/CAVEAT (OF DOCUMENT)

2. TITLE

Impact to Defence of Lessons Learnt using Modern Precision Strike Weapons

3. SECURITY CLASSIFICATION (FOR UNCLASSIFIED REPORTS THAT ARE LIMITED RELEASE USE (L) NEXT TO DOCUMENT CLASSIFICATION)

Document	(U)
Title	(U)
Abstract	(U)

4. AUTHOR(S)

Nicola K. Molloy

5. CORPORATE AUTHOR

Systems Sciences Laboratory
PO Box 1500
Edinburgh South Australia 5111 Australia

6a. DSTO NUMBER	6b. AR NUMBER	6c. TYPE OF REPORT	7. DOCUMENT DATE
DSTO-GD-0360	AR-012-604	General Document	3 April 2003

8. FILE NUMBER	9. TASK NUMBER	10. TASK SPONSOR	11. NO. OF PAGES	12. NO. OF REFERENCES
E9505/23/158	AIR 01/256	DGAD	43	20

13. URL on the World Wide Web

http://www.dsto.defence.gov.au/corporate/reports/DSTO-GD-0360.pdf

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16. DELIBERATE ANNOUNCEMENT

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17. CITATION IN OTHER DOCUMENTS Yes

18. DEFTEST DESCRIPTORS

Precision guided weapons, weapon systems, planning

19. ABSTRACT

This report details research performed in the area of air-to-surface, precision strike weapons. The open literature has been reviewed and documents that relay information on precision weapons used in military operations over the last 20+ years have been studied. The points considered during this research include; intelligence support and operations planning; time critical targeting (mobile and relocatable); effects of weather and countermeasures; weapon use and effectiveness analysis; timely combat assessment; and the relevance to the ADF. These are discussed in relation to the lessons learnt from three of the military operations fought in the last half-century. Namely, Operations Desert Shield/Storm, Allied Force and Enduring Freedom.